

# CONCURRENT SCHEDULES: EFFECTS OF TIME- AND RESPONSE-ALLOCATION CONSTRAINTS

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Five pigeons were trained on concurrent variable-interval schedules arranged on two keys. In Part 1 of the experiment, the subjects responded under no constraints, and the ratios of reinforcers obtainable were varied over five levels. In Part 2, the conditions of the experiment were changed such that the time spent responding on the left key before a subsequent changeover to the right key determined the minimum time that must be spent responding on the right key before a changeover to the left key could occur. When the left key provided a higher reinforcer rate than the right key, this procedure ensured that the time allocated to the two keys was approximately equal. The data showed that such a time-allocation constraint only marginally constrained response allocation. In Part 3, the numbers of responses emitted on the left key before a changeover to the right key determined the minimum number of responses that had to be emitted on the right key before a changeover to the left key could occur. This response constraint completely constrained time allocation. These data are consistent with the view that response allocation is a fundamental process (and time allocation a derivative process), or that response and time allocation are independently controlled, in concurrent-schedule performance.

*Key words:* concurrent schedules, response allocation, time allocation, feedback functions, key peck, pigeons

When the ratio of rates of reinforcers is varied on concurrently available variable-interval (VI) schedules, the ratios of both the numbers of responses emitted and of time spent responding are a power function of the reinforcer-rate ratio. This relation is known as the generalized matching law (Baum, 1974, 1979; Davison & McCarthy, 1988). Under a logarithmic transformation, this relation is written:

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{R_1}{R_2}\right) + \log c.$$

$B$  refers to the behavioral measure (responses emitted or time allocated),  $R$  refers to the reinforcers obtained, and the subscripts denote two alternatives. The putative constant  $a$  is called sensitivity to reinforcement (Lobb & Davison, 1975); it measures the rate of change in the log of the behavior ratio with changes

in the obtained log reinforcer ratio.  $\log c$  is called bias; it measures any preference for one response over the other that remains constant as the log reinforcer ratio is changed.

The two dependent variables, response allocation and time allocation, are usually highly correlated such that the  $a$  values for each ( $a_r$  and  $a_t$ ) are similar but not identical. The available evidence (Taylor & Davison, 1983) for concurrent VI VI performance suggests the following: For VI schedules based on arithmetic progressions of intervals,  $a_r$  is less than  $a_t$ , whereas for exponential VI schedules (as used here),  $a_r$  is not significantly different from  $a_t$ . The arithmetic-schedule results suggest that response allocation and time allocation may be controlled to differing extents by reinforcer-ratio variations. There is further evidence that response- and time-allocation measures may not always covary exactly. Rider (1979) arranged various concurrent fixed-ratio (FR) variable-ratio (VR) schedules with rats. With these schedules,  $a_r$  is trivially 1.0. However,  $a_t$  was between 0.69 and 0.77 for the 4 subjects (Davison & McCarthy, 1988). Herrnstein and Heyman (1979) arranged concurrent VI VR schedules with pigeons and reported that performance was biased toward the ratio schedule for response measures but toward the interval schedule for time measures. LaBounty and

The research reported here was supported by grants from the New Zealand University Grants Committee and from the Auckland University Research Committee, both of whom I thank. Douglas Elliffe and Philip Voss provided useful criticisms of a version of this paper, and I thank them both. I also thank Carol Philips, Odette Miller, Kevin Waugh, the masters and doctoral students, and the staff who helped run these experiments. Reprints may be obtained from Michael Davison, Department of Psychology, University of Auckland, Private Bag, Auckland New Zealand.

Reynolds (1973) trained rats on concurrent fixed-interval (FI) FR schedules. Their data (Baum, 1974) showed no significant bias for response measures, but showed a strong bias (averaging 0.28) toward the FI schedule for time measures. Hunter and Davison (1982) varied both the reinforcer-rate ratio and the force-requirement ratio on concurrent VI VI schedules with pigeons. For reinforcer-rate variation, time-allocation sensitivity was significantly greater than response-allocation sensitivity (the usual result for arithmetic schedules), but, for force-ratio variation, time-allocation sensitivity was significantly lower than response-allocation sensitivity. Finally, Davison and Ferguson (1978) reported data on concurrent VI VI schedules using pigeons, with one schedule requiring a lever press and the other a key peck. Bias toward the key was 0.65 for response measures and was much smaller, 0.32, for time measures. All these results are discussed at length by Davison and McCarthy (1988, Chapter 7). Together, they suggest that response and time measures on concurrent schedules can be different. The intention of the present experiment was to determine whether response and time measures in concurrent VI VI schedules can be either partially or completely dissociated. If, for instance, a constraint on time allocation constrains response allocation, the suggestion made by Baum and Rachlin (1969) that reinforcer variations in concurrent VI VI schedules directly control time allocations, and that response allocation follows time allocation because responding occurs at equal local rates on the two alternatives, will be supported. If, however, this does not occur, but a constraint on response allocation affects time allocation, the suggestion made by Baum and Rachlin may be incorrect.

The experiment reported here consisted of three parts. In Part 1, standard concurrent VI VI schedules were arranged, and the reinforcer ratio was varied. This provided a baseline against which the results of Parts 2 and 3 could be evaluated. In Part 2, time allocation on one alternative was constrained using a feedback function that required that the time spent on one key between changeovers could not exceed the time spent on the other key between changeovers. In Part 3, a similar feedback function was used, but it constrained response allocation so that the number of responses on one key between changeovers could not exceed

the number emitted on the other key between changeovers. In both Parts 2 and 3, the reinforcer ratio provided by the concurrent VI VI schedules was varied. Would a time-allocation constraint affect response allocation (Part 2) and/or a response-allocation constraint affect time allocation (Part 3)?

## METHOD

### *Subjects*

Five homing pigeons, numbered 111, 113, 114, 115, and 116, were maintained at  $85\% \pm 15$  g of their free-feeding body weights. The subjects had extensive previous experience on concurrent-chains schedules (Alsop & Davison, 1988) in the same experimental chamber.

### *Apparatus*

All experimental contingencies were programmed on a PDP® 11/73 computer using SKED-11® software. The computer was situated remotely from the experimental chamber. The chamber was 330 mm high, 330 mm wide, and 310 mm deep, and it was fitted with an exhaust fan to provide ventilation and to help mask external noise. Three response keys, 20 mm in diameter, 110 mm apart, and 250 mm from the grid floor, were on one wall of the chamber. Only the left and right keys, which could be transilluminated white, were used in the present experiment, and the center key remained blacked out and inoperative at all times. When lit, the keys were operated by pecks exceeding about 0.1 N. The food magazine was situated beneath the center key and 120 mm from the floor. During reinforcement (which was 3-s access to wheat throughout), the food hopper was raised and illuminated, and the keylights were extinguished. There was no other source of illumination in the chamber.

### *General Procedure*

Because the pigeons were experienced, no shaping was necessary; therefore, the subjects were placed directly on Condition 1 (Table 1).

Independent exponential concurrent VI VI schedules were arranged in all parts of the experiment. The individual VI schedules were arranged in this way: Every 1 s, a probability gate was interrogated (with the probabilities set at the values shown in Table 1), and reinforcers were arranged for the two responses accordingly. Once a reinforcer had been ar-

ranged on a key, the gate for that key was not sampled again until that reinforcer had been delivered. The relative reinforcer rate obtained on the two keys was varied by changing the probability of reinforcement per second on the two keys separately, as shown in Table 1. A changeover delay (Herrnstein, 1961) arranged that a reinforcer could not be obtained on a key until the subject had been responding on that key for 3 s after changing over between the keys.

The daily sessions commenced with the two side keys illuminated white, and they ended with these keylights extinguished after 40 reinforcers had been obtained or after 44 min had elapsed, whichever occurred first. The numbers of responses on the left and right keys, the time (in 0.1-s steps) spent responding on the two keys (from the first peck on a key to the first peck on the other key), the numbers of reinforcers obtained on the two keys, and the number of changeovers from the left to the right keys were recorded. After each session, the pigeon was returned to its home cage (where water was always available) and was fed the amount of mixed grain necessary to maintain its designated body weight.

Each experimental condition remained in effect until all 5 subjects had reached a stability criterion five times, at which point the experimental conditions were changed for all subjects. The criterion required that the median relative left/(left + right) response numbers over a set of five sessions did not differ by more than .05 from the median of the previous set of five sessions. Thus, stability could not be achieved in under 14 sessions. Typically, when an individual subject had met the stability criterion five times, its relative behavior allocation remained stable until the condition was changed. The number of sessions that each condition was in effect is shown in Table 1.

#### Part 1

In Part 1 (Conditions 1 to 5), the contingencies described above were arranged. The relative left-key reinforcer frequency was varied over five experimental conditions (Table 1).

#### Part 2

In Part 2 (Conditions 6 to 12), the following additional contingencies were arranged. When the subject changed over from the left key to the right key, the first right-key peck turned

Table 1

Sequence of experimental conditions, number of training sessions given in each condition, and the probability (times 1,000) of reinforcers per second on the left and right keys.

Condition	Sessions	$p(\text{Rft/s}) \times 1,000$	
		Left	Right
Part 1			
1	29	32	4
2	26	4	32
3	26	29	7
4	20	7	29
5	18	18	18
Part 2			
6	20	18	18
7	19	7	29
8	39	32	4
9	19	29	7
10	22	4	32
11	23	33	3
12	21	3	33
Part 3			
13	28	18	18
14	22	7	29
15	27	32	4
16	17	3	33
17	24	29	7
18	17	4	32
19	23	33	3

off the left key and made it inoperative for a time equal to the time that the bird had just spent responding on the left key (the time from the first left-key peck to the subsequent right-key peck). Then both keys were illuminated and the bird was again free to changeover and respond to the left key. The left-key schedule continued timing when the left key was off. This procedure ensured that the subject could not spend more time responding to the left key than to the right key, though it could spend more time responding to the right key than to the left key. Under these conditions, the relative left-key reinforcer rates were varied over seven experimental conditions (Table 1).

#### Part 3

In Part 3 (Conditions 13 to 19), contingencies similar to those in Part 2 were arranged with the following difference: Instead of the time spent responding on the left key determining the minimum time that could be spent responding on the right key, the number of responses emitted on the left key after a changeover to the left key determined the number of responses that had to be emitted to the

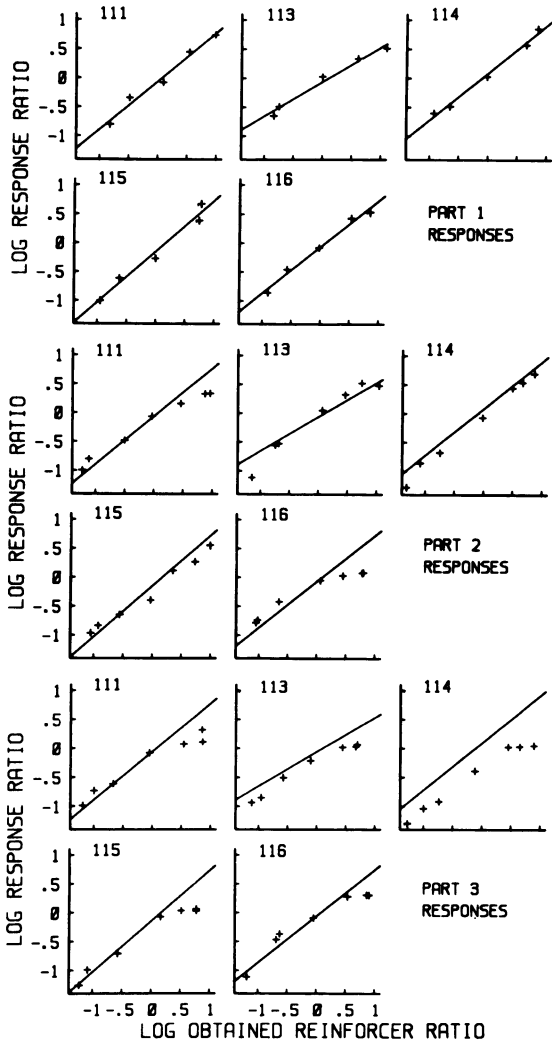


Fig. 1. The log ratio of responses emitted as a function of the log ratio of reinforcers obtained for each individual subject in each condition. Part 1 was standard concurrent VI VI schedules, Part 2 contained a time-allocation constraint, and Part 3 contained a response-allocation constraint. The straight lines are the fitted lines for each individual subject in Part 1.

right key before the left key was again available. This procedure ensured that the subject could not emit more responses on the left key than on the right key, though it could emit more responses on the right key than on the left key. Thus, in Part 3, the availability of the left-key schedule was contingent upon a variable number of responses being emitted on the right key, whereas in Part 2, it was contingent only upon the elapsing of a variable

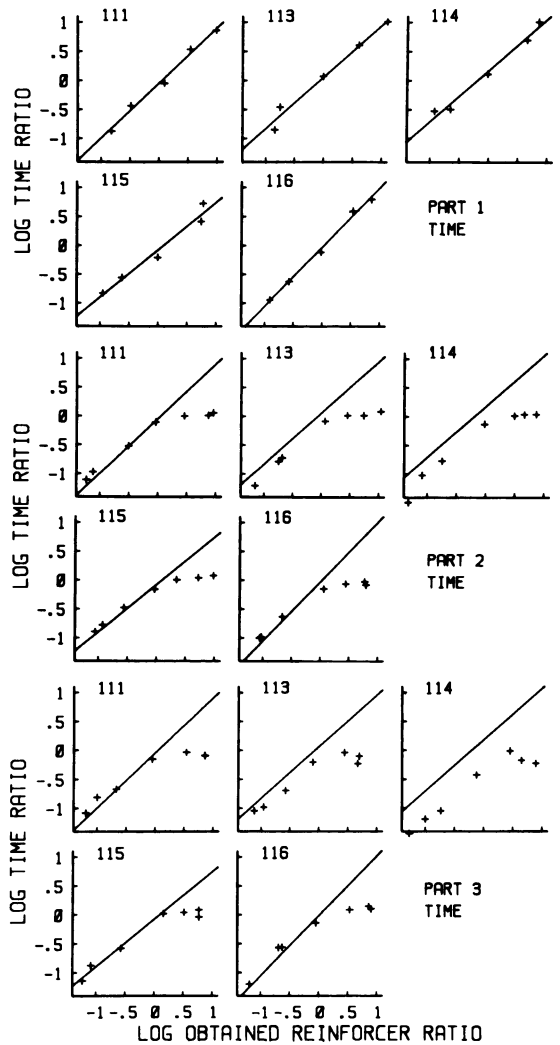


Fig. 2. The log ratio of time spent responding as a function of the log ratio of reinforcers obtained for each individual subject in each condition. Part 1 was standard concurrent VI VI schedules, Part 2 contained a time-allocation constraint, and Part 3 contained a response-allocation constraint. The straight lines are the fitted lines for each individual subject in Part 1.

time period. In Part 3, the relative left-key reinforcer rates were again varied over seven experimental conditions.

## RESULTS

The numbers of responses emitted, seconds spent responding, reinforcers obtained on the left and right keys, and the number of changeovers from the left to right keys are shown for

each bird and each condition in the Appendix. These data have been summed over the last five sessions of each condition. It is evident from these data that the time-allocation constraint used in Part 2 (Conditions 6 to 12) and the response-allocation constraint used in Part 3 (Conditions 13 to 19) were effective in controlling these dependent variables. It is also evident that no examples of exclusive preference were obtained.

### *Part 1*

Figures 1 and 2 show, respectively, log response- and time-allocation ratios as a function of obtained log reinforcer ratios for all three parts of the experiment. Straight lines were fitted to the data from Part 1 by the method of least squares, and the results of these regressions are shown in Table 2, along with the standard deviations of the parameter estimates and the percentage of variance accounted for. These fitted lines are also plotted on the results from all three parts in Figures 1 and 2. Straight lines fit the Part 1 data well, with not less than 97% (responses) or 96% (time) of the variance accounted for. The Part 1 sensitivity of response measures to reinforcer ratios was less than 1.0 for each individual subject (though not significantly different from 1.0 for Bird 115), and sensitivity for the group data was 0.77. These values are, on the average, rather lower than those for concurrent exponential schedules calculated by Taylor and Davison (1983). Part 1 time-allocation sensitivity (on average, 0.92) was less than 1.0 for 4 of the 5 birds, but was not significantly different (more than 2 standard deviations away from) 1.0 for any individual. Four of the five values were lower than the mean for these schedules calculated by Taylor and Davison. Time-allocation sensitivities were greater than response-allocation sensitivities for 4 of the 5 birds, a result that is nonsignificant on a sign test and is consistent with the findings of Taylor and Davison. The results, therefore, generally accorded with previous concurrent exponential VI VI results and provided a good baseline on which to assess the effects of time- and response-allocation constraints in Parts 2 and 3.

Figure 3 shows the results from the three parts of the experiment averaged across the 5 subjects. Two lines have been plotted on the data from the three parts: a line of slope 1.0

with 0 intercept (a strict-matching line) and a line of slope 0 with 0 intercept. The latter helps to show the operation of the feedback functions used in Parts 2 and 3. In Part 1, average response and time ratios were always closer to indifference than predicted by strict matching (that is, undermatching occurred on average); this deviation was always greater for response allocation than it was for time allocation.

### *Part 2*

In Part 2, time allocation to the left key could not exceed that allocated to the right key. This feedback function operated correctly such that log time-allocation ratios were close to 0 when the left key provided the higher reinforcer rate (to the right of 0 log reinforcer ratios on the figures). For the group data (Figure 3), log time-allocation ratios were, on average, a little greater than 0. This occurred because the subjects emitted low changeover rates (large interchangeover times), with the session ending during responding on the left key. When the right key provided a higher reinforcer rate than the left key (to the left of the 0 log reinforcer ratio point), log time-allocation ratios were correlated with log obtained reinforcer ratios. However, log response-allocation ratios were directly correlated with log obtained reinforcer ratios across all variations of log reinforcer ratios. There was some evidence of a minor effect of the time-allocation constraint on response allocation for Birds 111, 113, and 116, and, in group data (Figure 3), especially at the highest log reinforcer ratio arranged (a ratio of 11 to 1). For Birds 111, 113, and 116, the slope of the relation between log response and reinforcer ratios appeared to be less steep to the right of the 0 log reinforcer ratio point. In general, to the left of this equality, time-allocation sensitivity was greater than response-allocation sensitivity, as was the case for 4 of the 5 birds in Part 1 and as is often the case in standard concurrent arithmetic (but not exponential [Taylor & Davison, 1983]) VI VI performance.

### *Part 3*

The response data from Part 3 (Figure 1, see also Figure 3) followed the feedback function quite closely although, by emitting very low changeover rates, 2 subjects (111 and 116) produced log response ratios consistently greater than 0 with the response constraint

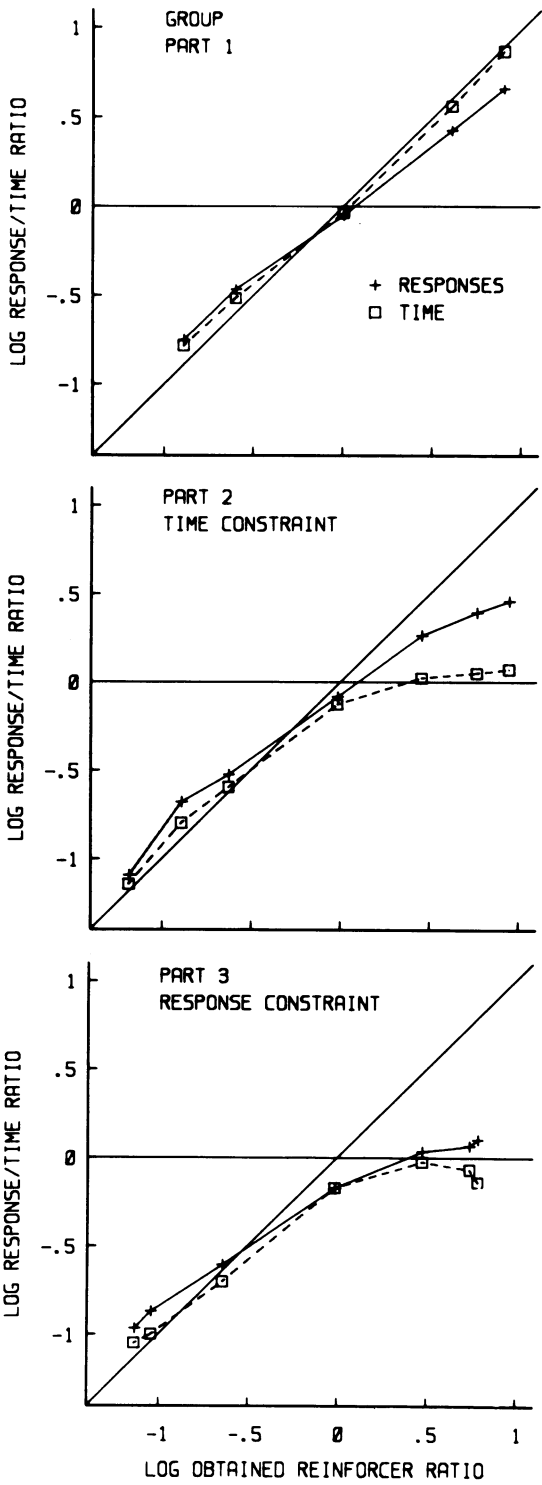


Fig. 3. The log ratio of responses emitted and times spent responding as a function of the log ratio of reinforcers obtained. The data shown have been averaged across the

Table 2

Results of linear regression analyses of the data from Part 1 for each individual subject and for the grouped data. VAC is the percentage of variance accounted for by the fitted line.

Subject	a (SD)	Log c (SD)	VAC
Part 1—Responses			
111	0.83 (0.07)	−0.06 (0.07)	98
113	0.59 (0.05)	−0.06 (0.09)	98
114	0.81 (0.04)	0.09 (0.07)	99
115	0.88 (0.09)	−0.15 (0.14)	97
116	0.80 (0.06)	−0.07 (0.09)	98
Group	0.77 (0.02)	−0.04 (0.03)	100
Part 1—Time			
111	0.95 (0.06)	−0.05 (0.08)	99
113	0.89 (0.08)	0.06 (0.13)	98
114	0.88 (0.07)	0.18 (0.11)	98
115	0.82 (0.09)	−0.08 (0.14)	96
116	1.03 (0.04)	−0.03 (0.07)	99
Group	0.92 (0.03)	0.02 (0.04)	100

operative. (With low changeover rates, and hence large interchangeover times, the session was likely to end with the subject responding on the left key.) It is noticeable from Figures 1 to 3 that, for most subjects and for the group, the obtained log reinforcer ratio in Condition 19 was significantly less extreme than that arranged. This resulted from the operation of the feedback function forcing the subjects to spend considerable time responding on the lower reinforcer-rate schedule.

The time-allocation data from Part 3 (Figures 2 and 3) were very strongly affected by the response-allocation constraints for all subjects. At the higher reinforcer ratios, the difference between the response- and time-allocation data indicates that, unlike standard concurrent VI VI results (Part 1), local response rates (responses per time allocated) were higher on the higher reinforcer-rate schedule than on the lower reinforcer-rate schedule. Comparing Parts 1 and 3, it seems that the response constraint affected performance even

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5 subjects. Part 1 was standard concurrent VI VI schedules, Part 2 contained a time-allocation constraint, and Part 3 contained a response-allocation constraint. Two straight lines are shown for each part: a line of slope 1 with 0 intercept (strict matching) and a line of slope 0 with 0 intercept.

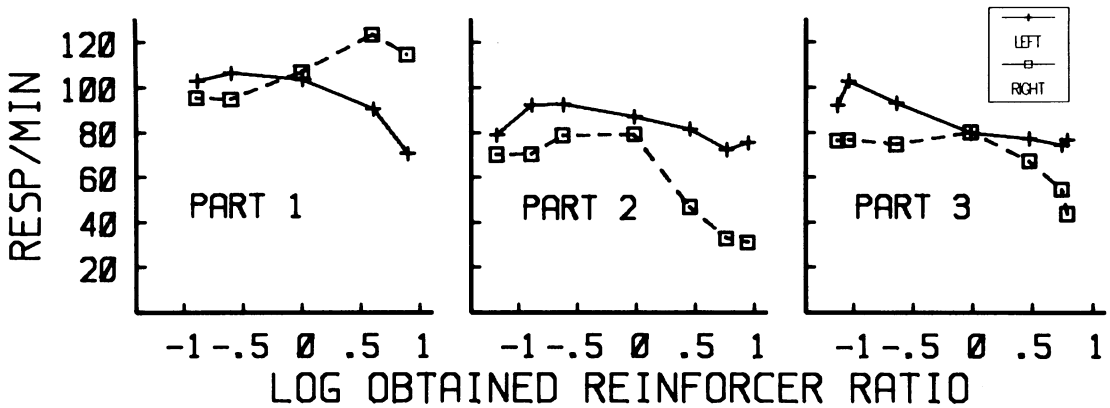


Fig. 4. Local response rates (per minute) as a function of obtained log reinforcer ratios for Parts 1 to 3. The data were averaged over the 5 subjects.

when the arranged (and obtained) schedules were equal.

Comparing Parts 2 and 3, it is evident from Figures 1 to 3 that the response-allocation constraint had a much more radical effect on time allocation than did the time-allocation constraint on response allocation. The large difference between the response- and time-allocation data in Part 2 indicates that the local response rates (responses per time allocated) in that part were much higher on the higher reinforcer-rate schedule than on the lower reinforcer-rate schedule. This could represent an absolute increase in the left-key local response rates or a decrease in the right-key local response rates, or both. If the effect was the first of these, the small effect of time-allocation constraints on response allocation might have been due to local response rates reaching a ceiling.

#### Local Response Rates

Figure 4 shows the local response rates on the two keys in the three parts of the experiment averaged across the 5 subjects. In Part 1, local response rates were higher on the key providing the lower reinforcer rates, representing the common finding that time-allocation sensitivity is greater than response-allocation sensitivity. In Part 2, when the right key provided the higher reinforcer rate, the time-allocation constraint produced no clear difference in the pattern of changes (though absolute local rates were a little lower) compared with Part 1. But when the right key provided the lower reinforcer rate, right-key local response rates were clearly depressed be-

low the level in Part 1. The response adaptation in Part 2 thus came about by responding at a lower local rate when the constraint forced the subject to spend more time than it would naturally spend (compare Part 1) on the lower reinforcer-rate schedule. Much the same was true of the results of Part 3 when the response constraint was used, although the response-rate suppression was a little smaller. Because of the response-allocation constraint in Part 3, the suppression that did occur increased only the time allocated to the lower reinforcer-rate key and thus further decreased the local response rate on that key. It is interesting to note that the local response-rate adaptation was similar in Parts 2 and 3, indicating a similarity in the effect of both types of constraint.

#### Local Reinforcer Rates

A measure that is directly related to melioration is the obtained local rate of reinforcers. These data are shown in Figure 5. In Part 1, the local rates of reinforcers were not equal but rather were directly correlated with the reinforcer rates obtained on a key. This result is just another way of showing that time-allocation sensitivity was less than 1.0—local reinforcer rates will be directly related to overall reinforcer rates whenever this is the case.

In Part 2 (Figure 5), much the same pattern as in Part 1 was observed when the right key gave the higher reinforcer rate. But when the left key gave the higher reinforcer rate (to the right of the equal-schedules point), because of the feedback function, allocating more time to the left key forced more time to be allocated

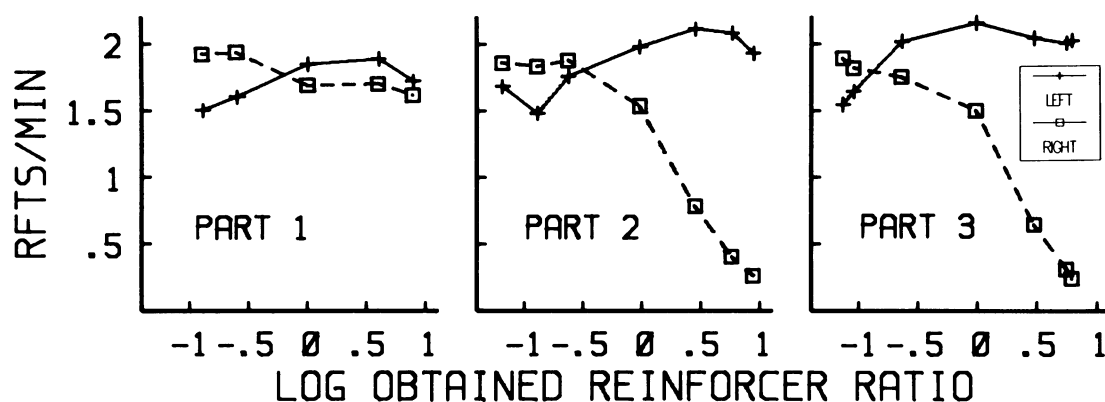


Fig. 5. Local reinforcer rates (per minute) as a function of obtained log reinforcer ratios for Parts 1 to 3. The data were averaged over the 5 subjects.

to the right key, and the right-key local reinforcer rates fell toward the overall rates of reinforcers scheduled on that key. In the same conditions, there was an apparent increase (compared with Part 1) in the local reinforcer rates obtained on the left key to a value above the arranged overall reinforcer rates. The results from Part 3 were similar to those from Part 2, but, compared with Part 2, the response-allocation constraint may have affected performance at lower log reinforcer-ratio levels, producing at these levels lower right-key, and higher left-key, local reinforcer rates.

#### *Interchangeover Times*

Figure 6 shows the interchangeover times (ICTs) for all three parts, averaged across the subjects. In Part 1, the ICTs followed the usual pattern (e.g., Stubbs & Pliskoff, 1969) for concurrent VI VI schedules, with the changeover rate (reciprocal of ICT) being greatest when the schedules were equal and becoming lower overall as the schedules were made more different. The pattern in Part 2 was quite different. When the right key gave a higher reinforcer rate than the left key (left side of the figure), the pattern was similar to that for Part 1 (notice that the range of log reinforcer ratios arranged in Part 1 was smaller than in Parts 2 and 3). But when the left key gave the higher reinforcer rate, the ICTs on both keys increased together as the reinforcer ratio increased. The fact that these ICTs were similar was caused simply by the operation of the feedback function. However, the feedback function

did not require that the ICTs increase—they could have remained short and equal.

The ICTs in Part 3 were very similar to those found in Part 2, although in Part 3 they were longer for the right key than for the left key when the left key gave the higher reinforcer rate. The similarity between the Part 3 left- and right-key ICTs (the right side of Figure 6) was not caused directly by the feedback function (which was a response constraint). Rather, the similarity arose from the relatively small differential in local response rates on the two keys (Figure 4). Again, the ICTs could have been different from each other, and could have been at the absolute level found in Part 1, had the subjects changed their local response rates sufficiently and changed over more frequently.

## DISCUSSION

Using concurrent VI VI schedules, the present experiment added the constraint that the minimum ICT on the right key equaled or exceeded the last ICT on the left key (Part 2), or the minimum number of responses on the right key between changeovers equaled or exceeded the number that had been emitted on the left key just prior to changing to the right key (Part 3). In terms of relative behavior allocation, the time constraint had a small effect on response allocation, but the response constraint had a major effect on time allocation.

Baum and Rachlin (1969) interpreted the (strict) matching law as a law of time allo-



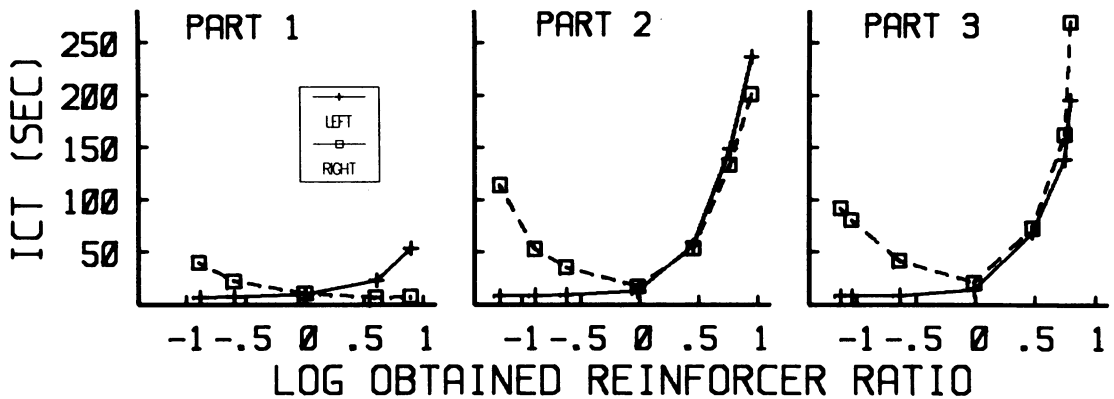


Fig. 6. Interchangeover times (seconds) as a function of obtained log reinforcer ratios for Parts 1 to 3. The data were averaged over the 5 subjects.

cation rather than as a law of response allocation. They did this on the basis of two sets of data. Baum and Rachlin arranged concurrent variable-time (VT) schedules in an experimental chamber with feeders at each end and in which the amount of time spent at each end could be measured. No explicit (e.g., pecking) response was required. They found that, on average, log time-allocation ratios matched log obtained reinforcer ratios. Brownstein and Pliskoff (1968) used a changeover-key concurrent-schedule procedure allowing their subjects to switch between VT schedules. They found a similar result. Baum and Rachlin noted that, although it would be possible to take the time spent responding as an index of the number of responses emitted, there is little empirical basis in the experiments of Brownstein and Pliskoff and Baum and Rachlin for assuming that time allocation measures number of emissions of unspecified responses. Thus, they suggested that these results supported the notion that animals fundamentally allocate time and respond at a constant tempo with occasional pauses that are proportional to the average interval between reinforcers on the alternatives. However, it is not a simple matter to prove the null hypothesis that no unspecified responses were being adventitiously reinforced in these two experiments. VT schedules may define no response requirements from the experimenter's point of view, but the extensive literature on superstition (Herrnstein, 1966) suggests that some responses may still come under strong control by reinforcers.

Because, in the present experiment, time-allocation constraints affected response allocation but response-allocation constraints did not affect time allocation, it seems that response allocation must be more fundamental. But there may be other explanations for the pattern of results obtained here that should be addressed before this conclusion is reached. These explanations are discussed below.

The first possibility is that, although time-allocation constraints (Part 2) do not act as response-allocation constraints, response-allocation constraints (Part 3) do also constrain time allocation. In this view, the present results are consistent with the notion that the control over response and time allocation could be independent in concurrent schedules. They are also consistent with the view that response allocation is the basic process. There are no available data on the degree to which response allocation might constrain time allocation. At the very least, responses themselves take up small amounts of time. But the time between responses is also an integral part of responding, so the degree to which response allocation forced time allocation in Part 3 could be substantial. The view that response allocation constrained time allocation in Part 3 also assumes that the tempo of responding is relatively constant (Baum & Rachlin, 1969). It was not found to be so in Parts 1 and 2 (Figure 4), but it is conceivable that the sorts of constraints used in Parts 2 and 3 would be more likely to decrease local response rates (through pausing) than to increase them. Thus, the possi-

bility of independent control of response and time allocation is not fully ruled out by the present data, and this approach would be completely consistent with the other experimental reports discussed in the Introduction. But even under this interpretation, the results of Part 2 are incompatible with Baum and Rachlin's suggestion that time allocation is fundamental and response allocation is derivative.

More local considerations can also argue against a clear interpretation of the present results. As one reviewer pointed out, in both Parts 2 and 3, changing over to the right key may have been punished by the removal of the left key and the reinforcers it provided, and this effect would probably be greatest when the left key provided the higher reinforcer rate. This may explain the lower right-key local response rates in Parts 2 and 3 compared with Part 1 when the left key provided the higher reinforcer rate. But only in Part 3 was there a contingency that required a variable number of right-key response to be emitted for the left key to again be available, accounting for the higher right-key reinforcer rates in Part 3 compared with Part 2 when the left key gave the higher reinforcer rate. This account cannot be countered within the design of the present experiment and requires further research. If it is correct, then the present experiment demonstrates some empirical effects of time- and response-allocation constraints on behavior allocation but says little that is germane to theories of response and time allocation.

The above discussion suggests that the results of the present experiment do not provide an unequivocal answer to the question of whether response or time allocation is fundamental or whether they are independent measures of different effects. They do suggest, however, that time allocation is probably not fundamental and response allocation derivative; these results, combined with those from previous research, may indicate that a reasonable working hypothesis is that the two are independent.

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Received February 1, 1990  
Final acceptance October 16, 1990

## APPENDIX

Numbers of responses emitted, seconds spent responding, and reinforcers obtained on both keys for each subject and condition. The number of changeovers (CO) from the left to the right keys is also shown. The data have been summed across the last five sessions of each condition.

Condition	Responses		Seconds		Reinforcers		CO
	Left	Right	Left	Right	Left	Right	
Bird 111							
1	9,167	1,678	5,574	775	181	19	129
2	1,567	9,999	777	5,838	26	174	103
3	9,371	3,370	5,267	1,555	155	45	209
4	3,300	7,280	1,514	4,166	49	151	204
5	5,719	6,879	3,253	3,658	110	90	359
6	5,058	5,861	2,772	3,575	95	105	223
7	3,194	9,718	1,667	5,577	47	153	183
8	7,088	3,334	4,761	4,643	176	24	46
9	6,243	4,333	4,104	4,107	148	52	102
10	1,204	7,695	635	5,956	14	186	74
11	8,141	3,777	5,354	4,716	180	20	20
12	759	7,579	458	5,898	11	189	59
13	4,397	5,311	2,889	4,136	94	106	182
14	2,091	8,592	1,260	5,887	35	165	133
15	7,216	5,634	5,031	6,315	160	22	24
16	849	8,284	503	6,041	12	188	56
17	7,171	6,100	4,705	5,128	155	45	46
18	1,742	9,467	1,006	6,575	18	182	84
19	8,349	4,023	4,937	6,090	156	22	9
Bird 113							
1	6,403	1,975	6,855	669	185	15	111
2	2,515	11,227	821	5,836	25	175	179
3	9,321	4,322	5,310	1,309	160	40	273
4	3,468	10,783	1,593	4,614	30	170	267
5	9,131	8,630	3,592	3,063	99	101	368
6	5,273	4,703	3,224	3,925	107	93	255
7	1,880	6,356	968	5,132	34	166	127
8	6,485	1,945	4,648	4,495	169	31	40
9	7,436	3,559	4,335	4,180	148	52	76
10	1,890	6,830	908	5,528	30	170	103
11	8,959	3,010	5,744	4,725	183	17	23
12	733	9,544	373	5,993	13	187	40
13	4,545	7,514	2,285	3,681	88	112	246
14	2,626	8,461	1,063	5,296	42	158	145
15	7,849	6,803	4,734	6,017	163	33	32
16	1,206	10,524	530	5,943	14	186	73
17	6,668	6,478	3,953	4,357	147	53	70
18	1,525	10,882	622	5,992	20	180	93
19	6,699	6,331	4,636	7,945	159	34	37
Bird 114							
1	8,610	1,231	6,211	617	175	25	87
2	2,117	8,517	1,572	5,282	21	179	190
3	7,434	2,019	5,105	1,038	163	37	157
4	2,945	8,990	1,714	5,410	36	163	253
5	6,064	5,732	4,122	3,182	97	103	298
6	5,599	6,556	3,037	4,108	97	103	224
7	1,595	7,653	845	4,999	30	170	103
8	7,092	2,061	4,691	4,315	164	36	34
9	6,976	2,523	4,236	4,105	151	49	73
10	1,133	8,243	580	6,054	15	185	73
11	8,446	1,717	5,455	4,980	176	24	31
12	406	7,708	203	6,311	9	191	32
13	2,694	6,654	1,762	4,757	86	114	209

APPENDIX (Continued)

Condition	Responses		Seconds		Reinforcers		CO
	Left	Right	Left	Right	Left	Right	
14	875	7,290	525	5,840	31	169	64
15	6,302	5,968	4,298	6,484	160	36	45
16	388	7,733	206	5,650	10	190	27
17	5,641	5,366	3,900	4,076	148	52	79
18	676	7,420	351	5,418	18	182	50
19	6,385	5,780	4,483	7,636	165	21	28
Bird 115							
1	5,683	1,203	5,926	1,110	171	29	123
2	841	8,559	736	5,008	20	180	129
3	5,088	2,102	4,742	1,834	169	31	258
4	1,530	6,308	1,439	5,205	38	162	236
5	2,365	4,451	2,656	4,314	99	101	366
6	1,668	4,188	3,149	4,593	96	104	210
7	976	4,369	1,671	5,008	43	157	130
8	4,598	2,485	5,034	4,603	168	32	29
9	3,903	3,034	4,240	4,195	138	62	56
10	687	4,750	955	5,740	21	179	75
11	4,679	1,313	5,389	4,524	181	19	18
12	514	4,762	748	5,883	16	184	86
13	2,788	3,325	4,014	3,868	118	82	164
14	954	4,942	1,474	5,655	42	158	151
15	3,836	3,330	5,081	4,209	171	29	54
16	496	4,856	753	5,687	15	185	74
17	3,675	3,425	4,703	4,303	153	47	53
18	262	4,806	442	6,170	11	189	50
19	3,957	3,714	5,021	5,538	171	29	29
Bird 116							
1	6,470	1,906	6,323	1,018	175	25	126
2	762	5,573	646	5,669	22	178	94
3	7,070	2,616	5,007	1,276	154	46	204
4	2,216	6,395	1,332	5,680	42	158	171
5	4,784	5,785	2,655	3,450	97	103	308
6	3,945	4,914	2,678	3,733	95	105	260
7	2,428	5,699	1,394	5,093	38	162	192
8	4,332	2,145	5,452	3,923	176	24	16
9	3,904	2,067	4,093	3,367	155	45	66
10	2,177	6,424	1,541	5,728	34	166	224
11	4,845	2,430	5,997	4,789	178	22	26
12	443	5,787	393	6,228	12	188	49
13	3,716	4,229	2,746	3,889	106	94	181
14	2,014	5,301	1,213	5,191	36	164	176
15	5,110	4,246	5,441	5,760	166	28	23
16	1,104	6,101	648	6,236	17	183	92
17	4,924	4,577	4,675	5,421	143	52	73
18	979	5,979	609	6,098	16	184	100
19	5,223	4,304	5,059	6,143	162	26	21